Inhomogeneous and Nonstationary Feature Analysis: Melding of Oceanic Variability and Structure (INFAMOVS)

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LONG-TERM GOALS

One of the primary research goals at the Rosenstiel School is real-time forecasting of both Lagrangian trajectories and Eulerian fields associated with such physical parameters as velocity, temperature, salinity, and density profiles. The five major components of this effort are (i) HYCOM the HYbrid Coordinate Ocean Model, (ii) data from Lagrangian drifters and satellite-derived sea surface temperature and height fields, (iii) a reduced-order information filter with a Gauss-Markov Random Field (GMRF) model for spatial covariances, (iv) a nonlinear particle dynamical model for Lagrangian trajectory prediction, and (v) feature-based parameter estimation and assimilation techniques.

OBJECTIVES

Scientific Objectives: Documenting, understanding, and predicting ocean variability using in-situ and satellite data, numerical ocean circulation models, statistical analysis, and data assimilation.

APPROACH

Our data analysis and assimilation approaches are based on motion-compensated space-time interpolation algorithms, state space reduction techniques, hodography, and multi-scale field decomposition.

WORK COMPLETED

A dynamical model for predicting Lagrangian trajectories in oceanic and coastal waters and an algorithm for optimizing its parameters given in-situ data were formulated and tested with Nathan Paldor and Tamay Ozgokmen. The model, which uses wind products and climatological ocean surface velocity data, showed that a simple choice of parameters for the friction and for the relative strength of

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14. ABSTRACT
One of the primary research goals at the Rosenstiel School is real-time forecasting of both Lagrangian trajectories and Eulerian fields associated with such physical parameters as velocity, temperature, salinity, and density profiles. The five major components of this effort are (i) HYCOM the HYbrid Coordinate Ocean Model, (ii) data from Lagrangian drifters and satellite-derived sea surface temperature and height fields, (iii) a reduced-order information filter with a Gauss-Markov Random Field (GMRF) model for spatial covariances, (iv) a nonlinear particle dynamical model for Lagrangian trajectory prediction, and (v) feature-based parameter estimation and assimilation techniques.

15. SUBJECT TERMS

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wind-driven particle motion versus climatological motion leads to a significant improvement in predicting particle motion in the tropical Pacific. Regional parameter values lead to better predictions. Our next task is to couple to this model to our Kalman filtering algorithm for Lagrangian prediction (see Ozgokmen, Griffa and Mariano progress report for details).

The Reduced Order Information Filter (ROIF) for the next generation of HYbrid Coordinate Ocean Models (HYCOM) was formulated and tested. Our methodology produced excellent results for a two-degree horizontal resolution simulation and we are presently porting the code to 1/3 degree and then 1/12 degree horizontal resolution HYCOM simulation of the North and Tropical Atlantic.

RESULTS

The Reduced Order Information Filter (ROIF) is a Kalman filter-based assimilation technique that utilizes Gaussian Markov Random Field (GMRF) to efficiently encode the covariance matrix. Numerical implementation of ROIF technology has been keeping pace with the developments in HYCOM in terms of both model physics and coding convention. The starting point was the ROIF implementation for a multi-layer eddy-resolving MICOM double-gyre simulation (Chin/Haza/Mariano, 2001). The hybrid use of GMRF in the horizontal (isopycnal) planes and empirical statistics in the vertical direction have been shown to be an effective tradeoff between the computational resource and accuracy of the analysis. This assimilation approach has then been tested on a 2-degree North Atlantic configuration with the new HYCOM with similar positive results. The difference in vertical coordinate system is the main distinction between MICOM and HYCOM. The use of empirical statistics in our implementation of ROIF has provided us with flexibility when porting the assimilation system from one ocean model to the other. The HYCOM code has just gone through a major make-over (i.e., the announcement of its first official model code, version 2). Presently, the ROIF is being re-coded for compatibility with this official HYCOM. At the same time, approaches used in the Ensemble Kalman filter are being incorporated to generate the empirical statistics needed along the vertical. An expected result is a hybrid of the ensemble approach and ROIF -- EnROIF.

The assimilation methodology of ROIF has also seen some mathematical maturity in recent months. Technical results in insuring the positive definiteness of the GMRF-covariance have been published (Chin, 2001). In addition, suitability of the GMRF-based approach (such as ROIF) to reconstruction of the meso-scale ocean features has been argued in terms of linear subspaces, and this idea has been presented at Fleet Numerical (FNMOC) and NRL (Monterey) and discussed with the scientists there. It is argued that a GMRF is able to represent a greater, effective subspace allowing ROIF to reconstruct a wider range of meso-scale feature geometry. This finding is being prepared as a submission to a scientific journal (Chin, 2001).

IMPACT/APPLICATIONS

These results are being applied to the NOPP-funded HYCOM modeling consortium's effort (see transitions) to produce a reliable and efficient ocean forecast system for the Navy.

TRANSITIONS

Bleck (LANL), Chassignet (RSMAS), Chin (JPL/RSMAS), Halliwell (RSMAS), Mariano (RSMAS), and Thacker (AOML) began a long-term collaboration with Barron, Hogan, Hurlburt, Jacobs, Wallcraft (all at NRL Stennis), Clancy (FNMOC,) Cayula and Smedstad (Planning Systems), Stathoplos (Orbimage), US Coast Guard Search and Rescue and International Ice Patrol that focuses on ocean modeling and prediction. This collaboration resulted in the NOPP-funded HYCOM modeling consortium.

Both Chin and Mariano visited FNMOC and NRL as a guest of Professor Andrew Bennett. We presented two seminars summarizing the Navy relevant aspects of our work and met with a number of oceanographers and meteorologists and discussed data assimilation methodologies and how to best evaluate ocean circulation models.

A complete summary of ocean surface currents is being constructed as a web-based reference system. We hope to finish the Atlantic Ocean by early 2002 and make our results available to the oceanographic community and for educational outreach.

RELATED PROJECTS

Mariano and Chin work closely with both the HYCOM modeling and RSMAS remote sensing groups. Strong collaboration with RSMAS scientists A. Griffa, D. Olson, T. Ozgokmen, as well as, and L. Piterbarg (USC) and N. Paldor (Hebrew U./RSMAS) on applied Lagrangian prediction will continue to be one of our primary near-term research activity. We are working with L. Shay and H. Peters on the analysis of high resolution in-situ coastal observations, with B. Parvin (LBNL) on feature velocity estimation and data mining in large geophysical data sets and with Wiggins (Bristol) and Lieken (CalTech) on the nonlinear dynamics of fluids. Related proposals are:

HYCOM Consortium for Data-Assimilative Ocean Modeling. NOPP-funded.
E.P. Chassignet (PI) with co-PIs R. Bleck, T. Chin, M. Clancy, G. Halliwell, H. Hurlburt, A.J. Mariano, M. O'Keefe, R. Rhodes, C. Thacker, A. Wallcraft

Predictability of particle trajectories in the ocean. ONR.
T. Ozgokmen (PI), A. Griffa, A.J. Mariano and N. Paldor (co-PI)

Four-dimensional Current Experiment. ONR. N. Shay (PI) with co-PIs H. Peters and A.J. Mariano

REFERENCES

PUBLICATIONS

Adler, R.J., R. Rosu, and A.J. Mariano. Estimating feature displacements velocities from scalar space-time data: application to sea surface temperatures.(Under revision, J. of Applied Statistics)

Chin, T.M., 2001. On Kalman filter solution of space-time interpolation. IEEE Trans. Image Processing 10: 663-666.

Chin, T.M., 2001. The covariance modes and error subspaces in Kalman filter: oceanic mesoscale reconstruction using orthogonal subspace. (in preparation)

Chin, T.M., A.C. Haza, and A.J. Mariano, 2001 A reduced-order information filter for multi-layer shallow water models: profiling and assimilation of sea surface height. (Accepted, Journal of Atmospheric and Oceanic Technology)

Garraffo, Z. D., A. J. Mariano, A. Griffa, C. Veneziani, and E. P. Chassignet, 2001. Lagrangian data in a high resolution numerical simulation of the North Atlantic.I: Comparison with in-situ drifter data, J. of Mar Sys, 29/1-4,157-176.

Garraffo, Z. D., A. Griffa, A. J. Mariano, and E. P. Chassignet, 2001. Lagrangian data in a high resolution numerical simulation of the North Atlantic. II: On the pseudo-Eulerian averaging of Lagrangian data, J. of Mar Sys, 29/1-4, 177-200.

Glover, D.M, S.C Doney, A.J. Mariano, R.H. Evans, and S.J. McCue, 2001 Mesoscale variability in time-series data: Satellite based estimates for the U.S. JGOFS Bermuda Time-Series Study (BATS) site (Accepted, J. Geophysic. Res.)

Mariano, A.J., T.M. Chin and E.H. Ryan, R. Kovach and O.B. Brown, 2001. On Gulf Stream Path Variability. (Submitted, J. Physical Ocean.)

Mariano, A.J., A. Griffa, T. Ozgokmen, and E. Zambianchi, 2001. Lagrangian Analysis and Predictability of Coastal and Ocean Dynamics 2000. (Submitted, J. of Atmos. and Ocean. Tech.)

Ozgokmen, T.M., L.I. Piterbarg, A.J. Mariano and E. Ryan, 2001. Predictability of drifter trajectories in the tropical Pacific Ocean. J. Physical Oceanography, 31, 2691-2720.

Paldor, N. and A.J. Mariano, 2001. An angular momentum perspective of the beta-plane approximation. (Submitted, Geophys. Research Letters).

Paldor, N., A.J. Mariano, T. Ozgokmen, and E.H. Ryan, 2001. Forecasting near-surface drifter trajectories in the Pacific Ocean with a hybrid particle model (In preparation)

Peters H., L. K. Shay, A. J. Mariano, and T. M. Cook, 2001. Current Variability on a Narrow Shelf with Large Ambient Vorticity (Accepted, J. Geophys. Res.).

Wilson-Diaz, D., A. J. Mariano, R. H. Evans, and M. E. Luther, 2001. A principal component analysis of sea surface temperature in the Arabian Sea. Deep Sea Research II, vol. 48, no. 6-7.

Yang, Q., B. Parvin and A. J. Mariano, 2001. Detection of vortices and saddle points in SST data. Geophysical Research Letters, Jan 15, 28 (2), 331-334.

Yang, Q., B. Parvin, A.J. Mariano, E. Ryan, R. Evans and O. Brown, 2001. Seasonal and interannual studies of vortices in sea surface temperature data (Submitted, International Journal of Remote Sensing,Oceanography from Space Venice 2000 special issue).

PATENTS

None